Large scale qualification of silicon micro-strip sensors for CMS tracker

Summary

The CMS tracker will extensively use silicon micro-strip sensors for energy and position measurements. It will implement 24244 sensors, representing the world wide tracker ever build.

To ensure the quality of silicon sensors and correct data collection during CMS experiments, a large scale qualification procedure has been developed by the CMS collaboration. After receiving and registration (CERN), the sensors and corresponding test structures are shipped to the Quality Test Centers (Karlsruhe, Perugia, Pisa, Vienna). These centers perform full characterization of samples of sensors and they are responsible for the overall quality of the sensors. A given percentage of the test structures and some sensors are distributed to the Quality Test Centers (Florence, Strasbourg, Vienna) where several parameters related to the production process are measured and long term tests are done. Further, test structures and sensors are sent to the Irradiation Qualification Centers (Louvain-la-Neuve, Karlsruhe) where neutron and proton irradiation are carried out.

Sensor quality control

The design characteristics of CMS sensors are optimally chosen in order to present better performance after high radiation damage predicted for LHC operations. The CMS sensors are manufactured by 6" planar technology from n-type wafers, with <100> crystal orientation. Different crystal resistivities, thickness and design geometries are foreseen as a function of sensors position in the tracker. Sensors are single sided (p^+ implantations performed on one side), poly-silicon resistors biased and AC-coupled to the read-out electronics.

To assure the quality of the sensors used for the tracker construction, optical inspection and full electrical characterization of samples of silicon sensors are performed by Quality Test Centers (QTC). Optical inspection consists in a survey by eye, an inspection under microscope and a metrology of few characteristic distances. During electrical characterization, the most important parameters of silicon sensors which contribute to the noise of the read-out electronics are measured:

- the leakage current of every strip for the shot noise contribution;
- the poly-silicon resistor which determines the bias parallel resistance noise;
- the current through the dielectric layer and the coupling capacitors which determine the pinholes.

Breakdown and depletion voltage are also determined by measuring the total leakage current and total capacitance.

The sensor quality control set-up will be described and statistical results based on quality control tests of about 6000 CMS sensors will be also presented.

Process quality control

The main purpose of the Process Control is to check the stability of the fabrication process and to identify in real time eventually problems which appear. In this way, a constant quality through the sensor production is ensured. The process control consists of characterization of the test structures produced on the same wafer as the sensor. The most important parameters required to be measured are the following:

- the thickness and the resistivity of wafers;
- the breakdown voltage of the decoupling capacitor oxide;
- the resistances of poly, aluminum and p^+ implant;
- surface leakage currents generated at the interface insulator / silicon.

The long term stability of the sensors at room temperature is also performed. This test checks for the leakage current to be below a specified value and stable in time. Such study is important because once the sensor is installed in the experiment, the access will be very limited.

The process quality control set-up will be described and statistical results based on process control tests of about 6000 CMS sensors will be also presented. Results of longtime test of sensors will be also presented.

Irradiation quality control

Over the ten years of LHC operations, CMS sensors will receive a mean fluence equivalent to 1.6×10^{14} neutrons (1 MeV) / cm^2. To ensure the required radiation hardness of the sensors, irradiation experiments using neutron and proton are performed. The neutron irradiation is carried out at Louvain-la-Neuve isochrone cyclotron and proton irradiation takes place at the Karlsruhe isochrone cyclotron .

The irradiation quality control consists mainly in electrical measurements, such as total leakage current and total capacitance, the evaluation of interstrip resistance and capacitances, measurement of the bias resistors and pinholes check (dielectric current and coupling capacitances).

General presentation of the neutron and proton irradiation set-up will be given. Results of irradiation quality control will be also presented.